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Gamma-ray Large Area Space Telescope (GLAST)

Large Area Telescope (LAT)

Calorimeter Contamination Control Plan (CCP)

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Table of Contents

1.0	PURPOSE.....	5
1.1	SCOPE.....	5
1.2	APPLICABLE AND REFERENCE DOCUMENTS	5
1.2.1	<i>CONTAMINATION CONTROL SPECIFICATIONS</i>	<i>5</i>
2.0	CONTAMINATION CONTROL REQUIREMENTS.....	6
2.1	SURFACE CLEANLINESS.....	6
3.0	CONTAMINATION SOURCES FOR CALORIMETER.....	6
4.0	CONTAMINATION ANALYSES AND LABORATORY TESTING.....	7
5.0	DESIGN PHASE CONTAMINATION CONTROL	7
5.1	MATERIALS SELECTION	7
6.0	FABRICATION AND ASSEMBLY PHASES CONTAMINATION CONTROL	8
6.1	VENTING DESIGN REQUIREMENTS FOR ACD AND SPACECRAFT	9
7.0	INTEGRATION PHASE CONTAMINATION CONTROL.....	9
7.1	CLEANROOM AND OPERATIONAL REQUIREMENTS.....	10
7.2	VACUUM BAKEOUT REQUIREMENTS	10
8.0	TEST PHASE CONTAMINATION CONTROL	11
8.1	VIBRATION AND ACOUSTICS TESTING	11
8.2	THERMAL BALANCE/THERMAL VACUUM TESTING	11
9.0	CONTAMINATION CONTROL DURING TRANSPORTATION AND STORAGE.....	12
10.0	ROLES AND RESPONSIBILITIES.....	12
11.0	CLEANLINESS INSPECTION AND MONITORING METHODS	12
11.1	CLEANING AND MONITORING SCHEDULES	13
12.0	EMPLOYEE TRAINING.....	13
13.0	CONTAMINATION DOCUMENTATION REQUIREMENTS	13
14.0	ACRONYMS AND DEFINITIONS.....	14
14.1	ACRONYMS.....	14
14.2	DEFINITIONS.....	14

1.0 PURPOSE

The purpose of this Contamination Control Plan (CCP) is to define the overall contamination control requirements associated with the Calorimeter. This plan defines the requirement for the contamination control of the Calorimeter, up to the point of integration with the GLAST LAT at SLAC.

1.1 Scope

The contamination control requirements for the Calorimeter, for all phases will be addressed, from design, through fabrication, assembly, integration, and testing. Calorimeter sensitivities and allowable contamination requirements will be presented, along with the planned methods for limiting contamination throughout all phases. Plans for analyses, laboratory investigations, cleanroom and hardware monitoring, will also be addressed. We will utilize existing methods, plans, documents, and lessons learned from previous, similar missions. Wherever possible, the Calorimeter program will utilize existing contamination control methods and documentation, which have already been developed for other missions at NRL.

1.2 Applicable and Reference Documents

The following subsections list the applicable and reference documents mentioned in this Calorimeter Contamination Control Plan. All documents are available through the GLAST LAT Project Office at SLAC.

1.2.1 CONTAMINATION CONTROL SPECIFICATIONS

FED-STD-209	Clean Room and Work Station Requirements, Controlled Environment
MIL-STD- 1246	Product Cleanliness Levels and Contamination Control
JSC SP-R-022A	Specification Vacuum Stability Requirements of Polymeric Materials for Spacecraft Applications
NASA Materials SN-C-0005C	Outgassing Data for Selecting Spacecraft Publication 1124 Materials Contamination Control Requirements for the Space Shuttle Program
GSFC-TLS-PR-7324-O 1	Contamination Control Procedures for the Tape Lift Sampling Surfaces
ASTM E-595	Methods of Test, Total Mass and Controlled Volatile Condensable Materials from Outgassing in a Vacuum Environment
IES-RP-CC-018-89-T	Cleanroom Housekeeping – Operating and Monitoring Procedures

2.0 CONTAMINATION CONTROL REQUIREMENTS

The overall Contamination Control program has been developed based on the sensitivities and performance goals of the GLAST LAT instrument. NRL is responsible for the development of the instrument contamination requirements. This section will present baseline contamination sensitivities and requirements.

All design, fabrication, assembly, integration, testing, packaging, transportation, integration with LAT must be performed in a manner, which will minimize the probability of contaminating Calorimeter critical surfaces.

During many project phases, an active contamination monitoring program will be in effect, using a number of methods, including visual inspections, black light and white light measurements, tape lifts and/or witness plates. Outgassing requirements will be met by all subsystems and/or components through proper selection of materials and appropriate vacuum bakeout of parts, components, and subsystems.

Generally, assembly and integration will take place in a class 100,000 or better cleanroom environment at NRL. When the instrument is outside of the class 100,000 cleanroom it must be bagged. The only exception is when I&T activities would prohibit bagging. Additionally, when flight hardware is not being worked on in the cleanroom it must be protected with a cover or drape. During any type of transportation or storage the satellite will be bagged in approved cleanroom bagging material.

The Calorimeter will be purged continuously with dry nitrogen gas. As a goal, after integration of the GLAST LAT, the calorimeter will be maintained in a class 10,000 environment. When in a class 100,000 environment the instrument must be bagged.

2.1 Surface Cleanliness

Calorimeter Component molecular and particle surface cleanliness requirements for delivery, Beginning-of-Life (BOL), and End-of-Life (EOL) will be evaluated and will be addressed separately. While the Calorimeter components will be cleaned periodically throughout the integration and assembly process, the optical elements are not baselined to be cleaned. Where contamination levels cannot be measured through contact test methods (tape lifts or rinses on optics for example), the levels will be inferred through black light inspection or measurement of witness plates maintained in the same environment as the sensitive surface.

3.0 CONTAMINATION SOURCES FOR CALORIMETER

Possible sources of contamination must be identified in order to protect Calorimeter from contamination and to effectively clean contaminated components. Table 3-1 is a listing of possible contamination sources at the various development stages.

Table 3-1 Contamination Sources for Calorimeter

Mission Phase	Molecular	Particulate
Fabrication	materials outgassing, machining oils, fingerprints, air fallout	shedding, flaking metal chips, filings, air fallout, personnel
Assembly & Integration	air fallout, outgassing, personnel, cleaning, solvents, soldering, lubricants, bagging material	air fallout, personnel, soldering, drilling, bagging material, shedding, flaking
Test	air fallout, outgassing, personnel, test facilities, purges	air fallout, personnel, test facilities, purges, shedding, flaking, redistribution
Storage	Bagging material, outgassing, purges, containers	bagging material, purges, containers, shedding, flaking
Transport	Bagging material, outgassing, purges, containers	bagging material, purges, containers, vibration, shedding, flaking
Launch Site	Bagging material, air fallout, outgassing, personnel, purges	bagging material, air fallout, personnel, shedding, flaking, checkout activities, other payload activities
Launch/Ascent	Outgassing, venting, engines, companion payloads separation maneuvers	vibration and/or redistribution, venting, shedding, flaking
On-Orbit	Outgassing, UV interactions, atomic oxygen, propulsion systems	Calorimeter cloud, micrometeoroid & debris impingement, material erosion, redistribution, shedding, flaking, operational events

4.0 CONTAMINATION ANALYSES AND LABORATORY TESTING

Wherever possible, previous analyses and laboratory testing performed for other will be utilized on behalf of Calorimeter. However, a number of contamination analyses and laboratory testing may be required in support of the GLAST LAT mission. These analyses and laboratory activities include:

- Materials evaluation analyses and testing for materials not previously characterized
- Molecular mass transport analyses
- Particulate accumulation and redistribution analyses (using existing analyses)
- Atomic oxygen erosion evaluations (using existing analyses)

5.0 DESIGN PHASE CONTAMINATION CONTROL

Contamination prevention is a basic design consideration and will be examined throughout the development process.

5.1 Materials Selection

In order to control contamination and protect sensitive surfaces, the use of minimal contaminating materials and the use of covers and protective shields must be considered. Manufacturing materials should be low outgassing, non-shedding and non-flaking. Generally, materials must meet the JSC SP-R-022A outgassing requirements. Efforts will be made to select low outgassing materials (CVCM level of 0.1% and TML of 1.0% by weight) for all applications. For questionable materials, or materials where data does not exist, it may be necessary to test outgassing characteristics in the GSFC MOLEKIT facility, in accordance with the ASTM E595; "Methods of Test, Total Mass and Collected Volatile Condensable Materials from Outgassing in a Vacuum Environment" procedure.

6.0 FABRICATION AND ASSEMBLY PHASES CONTAMINATION CONTROL

Fabrication and assembly of Calorimeter will generally take place in uncontrolled environments (> Class 100,000 environments). During all fabrication and assembly phases and associated storage/transportation periods, contamination control measures will be instituted. Surfaces will be kept clean, and if any debris is generated during the manufacturing process it will be cleaned/vacuumed off. During assembly, mating surfaces will be cleaned to visibly clean sensitive prior to attachment. All interior volumes will be cleaned thoroughly prior to final assembly and attachment. Isopropyl alcohol or a 3 to 1 mix of IPA with 1,1,1 -Trichloroethane may be used as a solvent. All ground support equipment will be kept visibly clean during assembly. Any cables, harnesses, etc. will be cleaned before attachment to flight hardware, and if necessary vacuum baked prior to outgassing certification.

Calorimeter subsystems will be maintained at a visibly clean level throughout the fabrication process. Trained personnel will perform inspections. Cleanliness requirements during subsystem fabrication are as follows:

1. During manufacturing operations such as machining, welding and soldering contaminants should be cleaned off of the hardware by wiping and/or vacuuming. Lubricants and cutting oils (i.e. oils and greases) should be cleaned off as soon as possible after the manufacturing operation using appropriate solvents.
2. Prior to priming or painting a surface it should be free of particulate or molecular deposits and be inspected at a visibly clean level.
3. If an area becomes inaccessible during fabrication it must be cleaned and inspected to a visibly clean level before becoming inaccessible.
4. Upon the completion of a fabrication operation, the components will be subjected to a gross cleaning procedure involving solvent washes and particulate removal, yielding a visibly clean sensitive product with less than 1 mg/ft² NVR. Parts with less than 1 square foot of area may be grouped together into one NVR rinse for verification purposes. The fabricated components will then be bagged to negate contamination effects.
5. Parts, surfaces, holes and so forth must be cleaned with isopropyl alcohol (IPA) moistened wipes. Wiping should be in one direction only and each pass should be with a clean area on a wipe or using a new wipe for each pass. In some instances wipes will be ineffective and swabs moistened with alcohol maybe used. Cleaning will continue until all surfaces are visibly clean, upon inspection.
6. Any cleaning of painted surfaces will be done with the approval of the Calorimeter contamination engineer.

7. Prior to any final assembly, all surfaces must be vacuumed giving special attention to holes, crevices and riveted regions.
8. Assemblies will be visually inspected with a blacklight for external oil or grease deposits, and if any are found, the areas will be wiped with IPA moistened wipes, using a clean wipe area for each pass and wiping in one direction.

6.1 Venting Design Requirements for ACD and Spacecraft

When the instrument is in the thermal vacuum or orbit configurations, all venting [including multilayer insulation (MLI)] shall be in the anti-optics direction and shall not impinge on the optics. This applies not only to dedicated ascent depressurization vents but also to any orifice or opening that may act as a vent. Additionally, the vent “plume” path shall not intersect any portion of the instrument in such a manner as to result in return flux scattering to optical surfaces. Exceptions to this requirement may be granted on a case-to-case basis if it can be demonstrated that there is no risk of venting by-products entering the instrument optical cavities or contaminating sensitive instrument thermal control surfaces during thermal vacuum testing or on orbit.

The vent shall be designed to vent to a cryogenic plate or similar molecular trap during thermal vacuum testing if the effluent from the vent is expected to be large enough to pose a threat to the instrument during thermal vacuum. The number of vents shall be limited to facilitate thermal vacuum testing. The venting design shall be adequate to provide for launch-ascent depressurization.

NASA qualified parts normally meet the minimum vacuum stability requirements. Thermal vacuum bakeout, curing at elevated temperatures, and thermal bakeout are efficient methods of reducing unacceptable outgassing rates to acceptable levels. It is also sometimes possible to justify the use of materials not meeting this requirement by performing a controlled outgassing rate test (ASTM 1559) using the following temperatures: source shall be +1 0°C over maximum

orbit service temperature for the material, TQCM at -1 0°C under the minimum orbit temperature for the optics in the instrument.

7.0 INTEGRATION PHASE CONTAMINATION CONTROL

Integration of the Calorimeter will occur in a class 100,000 environment at SLAC. After Calorimeter integration the goal will be to keep the instrument in class 100,000 environment.

When in a class 100,000 environment the Calorimeter must be bagged. Regular monitoring of the cleanroom, GSE, and flight hardware will be accomplished. The Calorimeter instrument will be delivered to the cleanroom in a clean, double-bagged condition. Exterior Calorimeter surfaces will be verified as meeting Visibly Clean Sensitive upon receipt at the cleanroom. The Calorimeter will remain bagged after integration with the whenever operations permit.

During downtimes when hardware is not actively being worked on, or for weekends and other non-operational times, flight hardware will be kept covered with an approved cleanroom certified, anti-static bagging material. Bagging materials and drapes must be contamination and electrostatic discharge (ESD) approved.

To prevent electrostatic discharge (ESD) damage to any of the electronic components precautions beyond

contamination control measures may be required. This may mean using anti-static packaging films, ESD approved garments and grounded wrist straps. Additionally the temperature and humidity of the work environment will be controlled. Quality Assurance will determine the ESD sensitivity of the hardware.

7.1 Cleanroom and Operational Requirements

Calorimeter integration will occur in NRL primary cleanroom facility, which operates at class 100,000 (or better) per Fed. Std. 209. The following list highlights the planned contamination procedures to be implemented during integration activities:

1. The most sensitive hardware will be placed closest to the HEPA filters in the cleanroom and less sensitive hardware will be kept downwind from the more sensitive hardware.
2. Parts from a less controlled fabrication and assembly area will be cleaned to a visibly clean level prior to entry into the clean room.
3. The room temperature will be maintained at $70\pm5^{\circ}\text{C}$ and the relative humidity will be maintained at 30 to 50%. If at any time environmental conditions are not within these values, it must be reported to the QA, and the contamination control engineer.
4. The cleanroom will include an air particle monitor, and a group of contamination witness plates, which will be evaluated, on a periodic basis.
5. All surfaces will be cleaned to Visibly Clean Sensitive throughout integration activities. A solvent rinse will be used to verify the molecular levels meet the budgeted requirement.
6. Parts, which are machined, welded or riveted, will be inspected and re-cleaned, if necessary to meet the Visibly Clean Sensitive levels. A solvent rinse may be used to verify the molecular levels meet the budgeted requirement.
7. Personnel working in the cleanroom will wear appropriate cleanroom clothing, shoe coverings, etc. and latex gloves. When working with solvents polyethylene gloves should be worn.
8. Ground support equipment (GSE) required for testing will be cleaned with IPA to a visibly clean level, and bagged before going into the cleanroom. Surfaces, which will contact the instrument, must meet the requirements.
9. Oils, greases and other similar agents, which may be contamination hazards, will not be used during integration without the permission of the materials engineer and contamination engineer.
10. Joints or crevices will be covered during integration to minimize the build up of contaminating debris. Rivets, bolts, nuts and so forth must be cleaned to remove any type of contamination such as lubricants and machining oils prior to I & T. Fasteners, which are lubricated, will be cleaned with an appropriate solvent prior to being used during integration. Areas, which become inaccessible for cleaning must be cleaned and inspected prior to that time, and be bagged following that time.
11. All integration GSE, testing equipment, etc. will meet the visibly clean level.
12. If an instrument or hardware is removed for testing, or some other reason, it must be reverified to a cleanliness level visibly clean, highly sensitive before it can reenter the cleanroom.
13. The instrument support team is responsible for cleaning and maintaining their respective instruments during satellite integration and testing.

7.2 Vacuum Bakeout Requirements

Along with the selection of low outgassing materials for the Calorimeter a thermal vacuum bakeout program will be accomplished for the program if required.

In general:

1. The outgassing rate will be measured during thermal vacuum certification. The materials, parts, and subsystems will undergo a vacuum bakeout only if they do not meet their outgassing requirement.
2. All other structure, materials, assemblies, or components, which may be mounted without MLI or controlled venting, will be evaluated on a case-by-case basis to assess the need for vacuum bakeouts.
3. A GLAST LAT level thermal vacuum bakeout, in conjunction with the satellite thermal balance/thermal vacuum testing, will be utilized if the instrument does not meet its outgassing requirements.

8.0 TEST PHASE CONTAMINATION CONTROL

Following integration, Calorimeter will be subjected to a number of testing operations. Generally, contamination requirements during the testing phases are identical to those found in Section 7.0, Integration Phase.

Testing facilities will be held at 65 to 75°F temperature and 30 to 50% humidity conditions. If a particular test requires the removal of bagging, the personnel who come in contact with the instrument must wear cleanroom clothing, gloves, etc. If solvents are used, polyethylene gloves must be worn.

Post testing cleanliness inspections of external surfaces will be performed to assure that surface cleanliness levels have not been exceeded.

8.1 Vibration and Acoustics Testing

Closed out surfaces of the instrument will be bagged during vibration and acoustic testing except when prohibited by the performance of the test. During periods of inactivity, the instrument will be draped.

8.2 Thermal Balance/Thermal Vacuum Testing

The Calorimeter will undergo a TB/TV testing sequence, in conjunction with a period of outgassing certification. All tests will be monitored with a combination of the following instrumentation:

1. Temperature controlled quartz crystal microbalances (TQCMs),
2. Cold fingers and scavenger plates

In addition, cold plates will be used as required to minimize contamination from known high outgassing sources.

The Calorimeter level thermal vacuum test will be performed at SLAC. The chamber will be maintained at a class 100,000 environment. Cleanroom garments will be worn while working within the chamber. The thermal vacuum

test will be monitored with a series of TQCMs and with the aforementioned monitoring instrumentation. All temperature transitions will be controlled to minimize contamination.

Prior to thermal vacuum testing, the instrument will be cleaned and verified for cleanliness requirements, double bagged, then transported to the thermal vacuum-testing chamber.

Prior to loading the instrument into the chamber, the chamber background and ground support equipment outgassing levels will be measured and verified to meet the chamber certification levels.

Outgassing certification will be performed during the last hot cycle of thermal vacuum testing. During certification, the flight hardware must be maintained at its maximum on-orbit operation temperature. The hardware-outgassing rate will be measured with two TQCMs for at least eight consecutive hours. The TQCMs must be mounted within the chamber such that the TQCMs have a representative view of the flight hardware. The TQCMs will be maintained at $\sim 500^\circ\text{C}$ and $+5^\circ\text{C}$. If the flight hardware does not meet its outgassing requirements the hardware will be subjected to a bakeout.

Following thermal vacuum testing QA and the contamination engineer will visually inspect the cleanliness of the instrument. The structure will be double bagged and transported to the integration facility, or another testing facility. External surfaces will be inspected and verified as meeting integration phase surface cleanliness requirements.

9.0 CONTAMINATION CONTROL DURING TRANSPORTATION AND STORAGE

The modules will be bagged and purged, during storage or transportation. Subsystems and subassemblies, which do not have any special requirements for handling and storage prior to integration, will be cleaned to a cleanliness level of visibly clean and bagged unless integration or test activities prohibit it. The modules will be bagged with approved bagging material (RCAS 4200 or equivalent) at all times unless integration and test activities prohibit it. The calorimeter with instruments will be bagged and transported in a shipping container. The shipping container will be pre-cleaned, prior to transportation, to a visibly clean level. Temperature and humidity will be monitored in the shipping container. In addition witness plates will be mounted inside the shipping container to monitor the contamination environment during transportation.

10.0 ROLES AND RESPONSIBILITIES

The Contamination Control Engineer, Systems Engineer, Integration and Test Manager, and Quality Assurance Engineer will be responsible for ensuring that contamination control measures are implemented throughout the design, fabrication, assembly, integration, testing, storage and transportation, and all other phases.

11.0 CLEANLINESS INSPECTION AND MONITORING METHODS

Cleanliness Inspection methods which will be used for the GLAST LAT mission are witness plates, black and white

light inspections, washes, swab sampling and tape lifts. Descriptions of these techniques are as follows:

Witness Plates:

Witness Plates are used to determine NYR levels, particulate levels and fallout rates. Witness plates collect passively during cleanliness monitoring procedures. Witness plates should be placed as close as possible to contamination sensitive areas, to obtain the most accurate particulate readings.

Light Inspections:

Visual Inspection is done periodically using black (UV) light or white light, per JSC-SNC005C. Visibly clean, using white light, is the absence of all particulates and nonparticulates visible to the normal unaided eye (except corrected vision). UV inspection light sources are no less than 100 watts and located no more than 50cm from the inspected item. During UV inspection, light from other sources should not be more than 5 ft candles. If visual contamination is evident, the hardware must be cleaned and then reinspected under the same light conditions. If during UV inspection there is any evidence of fluorescence the item/surface must be re-cleaned. If re-cleaning does not reduce the fluorescence, it must be determined whether the fluorescing material is a contaminant or the substrate surface.

Molecular Washes/Wipes:

A surface, which is to be inspected, is washed or wiped with alcohol or an appropriate solvent and the solvent and residue is collected. This collected residue or rinse is then subjected to a quantitative and qualitative analyses and the type of contaminant residue is chemically identified.

11.1 Cleaning and Monitoring Schedules

Cleaning of flight hardware, GSE, and cleanrooms shall occur on a scheduled basis and as required by activities. The Contamination Control Implementation Plan (CCIP) shall present the planned cleaning and monitoring schedule.

12.0 EMPLOYEE TRAINING

Contamination Control and Cleanroom Practices training will be conducted for all personnel involved in the fabrication, assembly, integration, testing, transportation and integration to the LAT instrument. Areas which will be studied in the training sessions are as follows: Definition of contamination and how it affects the mission; the importance of maintaining contamination control in all the program phases, that is, fabrication through to launch; reviewing instrument sensitivities; knowledge of the instrument and contamination control plans and related contamination documents; specific techniques for cleaning, inspection, and packaging; monitoring techniques in the cleanroom and in the shipping containers; and cleanroom dressing procedures and rules for working in a controlled cleanroom area.

13.0 CONTAMINATION DOCUMENTATION REQUIREMENTS

There are a number of contamination-related documents, which must be produced and periodically updated throughout the development process. These include:

- Contamination Control Plan
- Cleanroom History Logs
- Hardware Cleanliness History Logs
- Testing Results Reports

14.0 ACRONYMS and DEFINITIONS

14.1 Acronyms

CCE	Contamination Control Engineer
CCM	Contamination Control Manager
CCP	Contamination Control Plan
CVCM	Collected Volatile Condensable Materials
ESD	Electrostatic Discharge
FED-STD	Federal Standard
GSE	Ground Support Equipment
GSFC	Goddard Space Flight Center
HEPA	High Efficiency Particulate Air
IPA	Isopropyl Alcohol
I & T	Integration and Test
MIL-STD	Military Standard
MLI	Multi-Layer Insulation
NASA	National Aeronautics and Space Administration
NVR	Non-Volatile Residue
PAR	Performance Assurance Requirements (Document)
QA	Quality Assurance
QCM	Quartz Crystal Microbalance
TML	Total Mass Loss
TQCM	Temperature-Controlled Quartz Crystal Microbalance
VCS	Visibly Clean Sensitive

14.2 Definitions

- Cleanroom - Room in which the concentration of airborne particles is controlled to specified limits.
- Clean Zone - Defined space in which the concentration of airborne particles is controlled to specified limits. Clean zones are classified by a number such as 1, 100, 1000, etc., in accordance with FED-STD-209, which describes the maximum number of particles, 0.1 microns and larger, permitted per cubic foot of air.
- Contamination - Any unwanted material that causes degradation in the desired function of an instrument or flight hardware.
- Contamination Control - Organized action to control the level of contamination.

- Fiber - A particle whose length-to-width ratio exceeds 10:1 with a minimum length of 100 microns.
- Gross Cleaning - Cleaning hardware surfaces to visual inspection standards.
- Level x per Mil-Std 1246 - The cleanliness level defined by a number and/or letter designating the particle distribution and molecular cleanliness, respectively.

Mil Std 1246 Particle Level	Percent Obscuration by Cylinder- Hemisphere
400	0.08
500	0.24
600	0.61
700	1.35
800	2.76
900	9.33

Mil Std 1246 Molecular Level	mg/ft ² NVR
A	1.0
B	2.0
C	3.0
D	4.0
E	5.0
F	6.0

- Nitrogen Purge - Pressurized flow of clean, dry nitrogen through a system in order to displace impurities and reactive species.
- Non-Volatile Residue - Soluble material remaining after evaporation of a volatile liquid which usually causes degradation in the desired function of an instrument or flight hardware.
- Particle - A small quantity of solid or liquid material with definable shape or mass with a length to width ratio less than 10:1.
- Particle Size - Expressed as the apparent maximum linear dimension or diameter of the particle.
- Precision Cleaning - A cleaning procedure done in a controlled environment to attain a specific level of cleanliness. This procedure follows gross cleaning.
- Sensitive Surface - Any surface of flight hardware that must meet a specified cleanliness level to assure the minimum performance levels.
- Solvent Flushing - Method of cleaning surfaces with a stream of filtered solvent under pressure, which is directed against a surface to dislodge and rinse away any foreign material.
- Solvent Washes - A quantitative method of verifying MIL-STD-1246 molecular cleanliness levels by measuring molecular contamination in a solvent, which was washed over a surface and collected.
- Surface Cleanliness Level - An established level of maximum allowable particulate and/or NVR contamination ranging from visibly clean to specific MIL-STD-1246 levels (e.g., Level bOA, Level 300B, etc.).
- Swab Sample - A qualitative method of identifying contaminants by analyzing the residue on a solvent-soaked swab that was wiped over a surface.
- Tape Lifts - A quantitative method of verifying MIL-STD-1246 particulate cleanliness levels by measuring particulate contamination on a sample of tape that has come in contact with the surface one wishes to examine.
- Vapor Degrease - Item to be cleaned is exposed to heated solvent vapors that condense on the part and wash away contaminant.
- Visibly Clean - The achievement of a clean surface as seen without optical aids (except corrected vision) as measured by a specified method.

Three levels of visibly clean (VC) requirements are defined in JSC-SN-C-0005C. Visibly clean is the absence of particles as seen by the unaided eye at the distance and light level specified below.

VC Level	Incident Light Level (Note-i)	Observation Distance	Remarks
Standard	>50 ft-candles	5-10 feet	Notes 2, 3, 4
Sensitive	>50 ft-candles	2-4 feet	Notes 2, 3, 4
Highly Sensitive	>100 ft-candles	6-18 inches	Notes 3, 4, 5

NOTES

Note 1: One foot-candle (lumens per square foot) is equivalent to 10.76 lumens per square meter.

Note 2: Cleaning is required if the surface in question does not meet VC under the specified incident light and observation distance conditions.

Note 3: Surfaces other than diffuse white may require additional cleaning to achieve these levels.

Note 4: Exposed and accessible surfaces only.

Note 5 :Initial cleaning is mandatory; Note 2 apply thereafter.